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Complex Adaptive System of Systems (CASoS) Engineering Initiative

http://www.sandia.gov/CasosEngineering/

The Role of Community Structure in Opinion Cluster Formation

Ryan J. Hammer, Thomas W. Moore, Patrick D. Finley, and Robert J. Glass
Sandia National Laboratories

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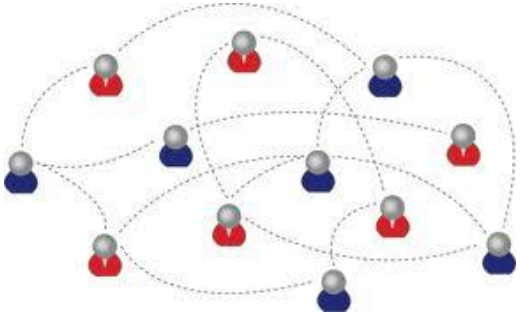
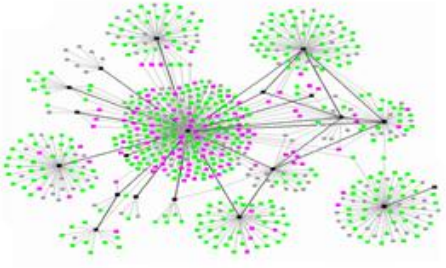
Outline

- Introduction
- Background
- Results
- Applications to public health
- Conclusion

Introduction

- Social networks represent people and relationships
  - Exhibit community structure





- **Question**: How does community structure affect opinion cluster formation?
- **Motivation**: Crafting effective public health policies

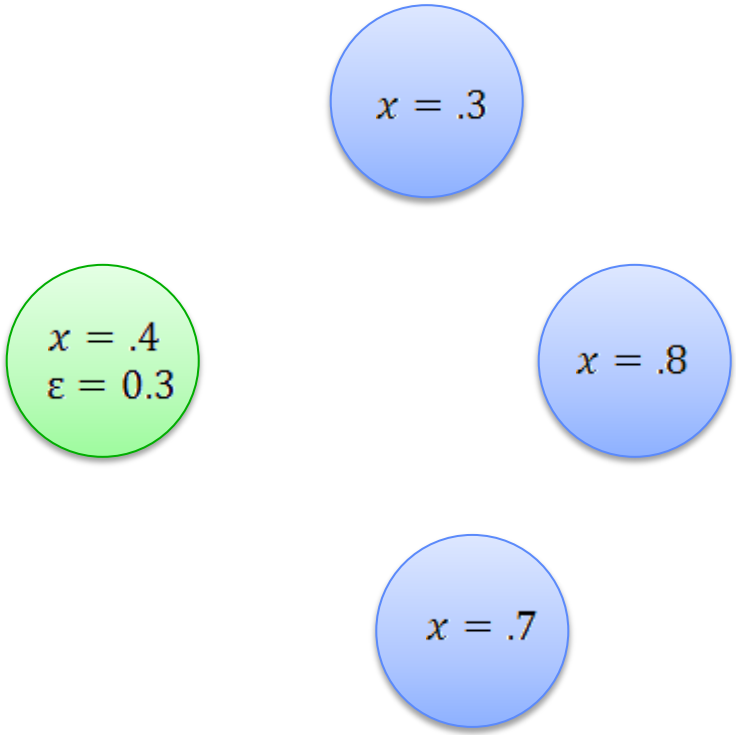
Opinion Dynamics

- Mechanism for modeling the flow of opinion through a group of individuals
  - Started from Ising Spin Alignment models
  - Grounded in structural balance theory
- Our model
  - Modified version of Deffuant & Weisbuch
  - Each individual holds an opinion represented as a continuous variable on the range [0,1]
  - Bounded confidence – *Tolerance*
    - Constrains opinion changing interactions– continuous variable on [0,1]
  - Mapped to a directed network

Opinion Dynamics in Action

$$\{k \in S_i : |x_i(t) - x_k(t)| \leq \varepsilon_i\}$$

$$x_i(t+1) = x_i(t) + \frac{1}{|S_i|} \sum_{k \in S_i} \mu_{ik} \left[x_k(t) - x_i(t)\right]$$



$$x_i(t+1) = 0.41$$

S_i: Set of out-degree neighbors
ε: Tolerance
μ: Plasticity
x: Opinion

Opinion Update Process:
1. Get out-degree neighbors
2. Update using out neighbors within tolerance bounds.
3. $x_i(t+1) = x_i(t)$ + *average of summed opinion difference*

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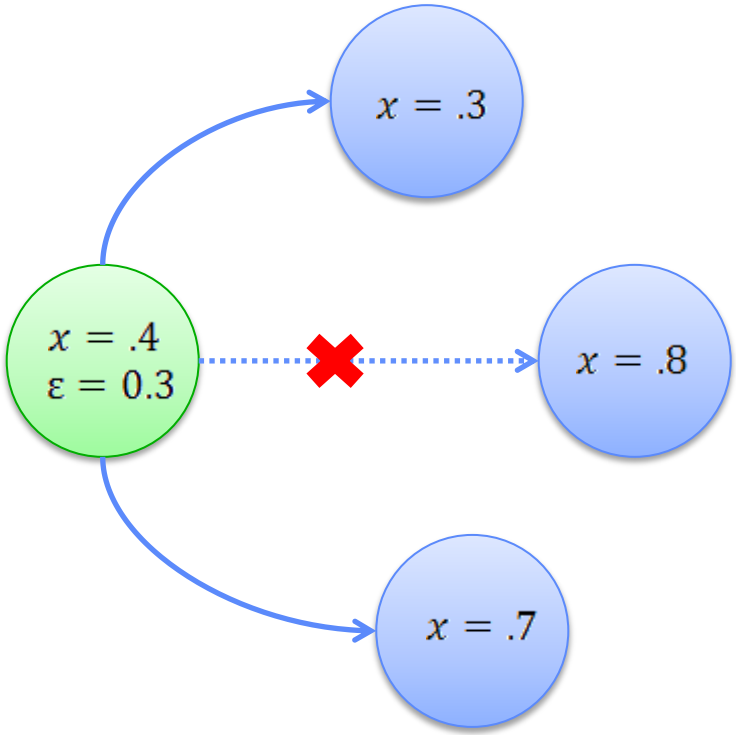

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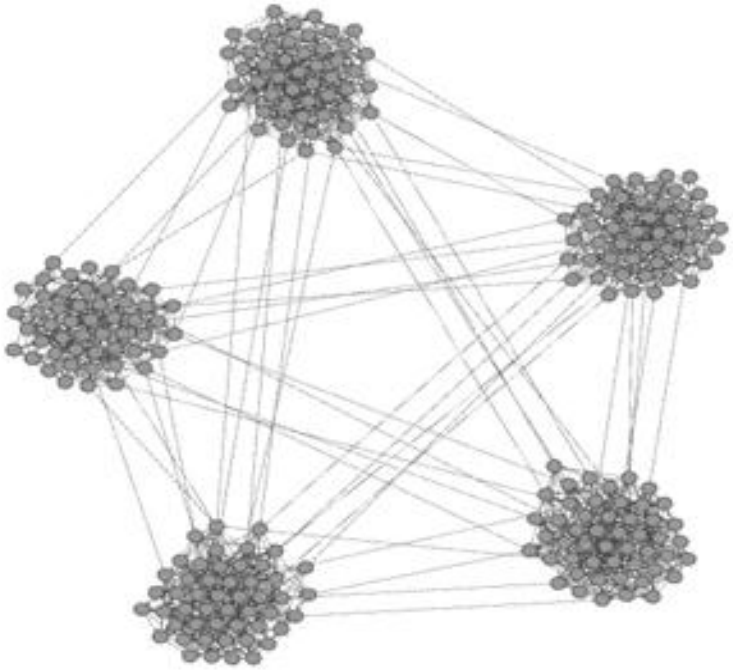
Setup

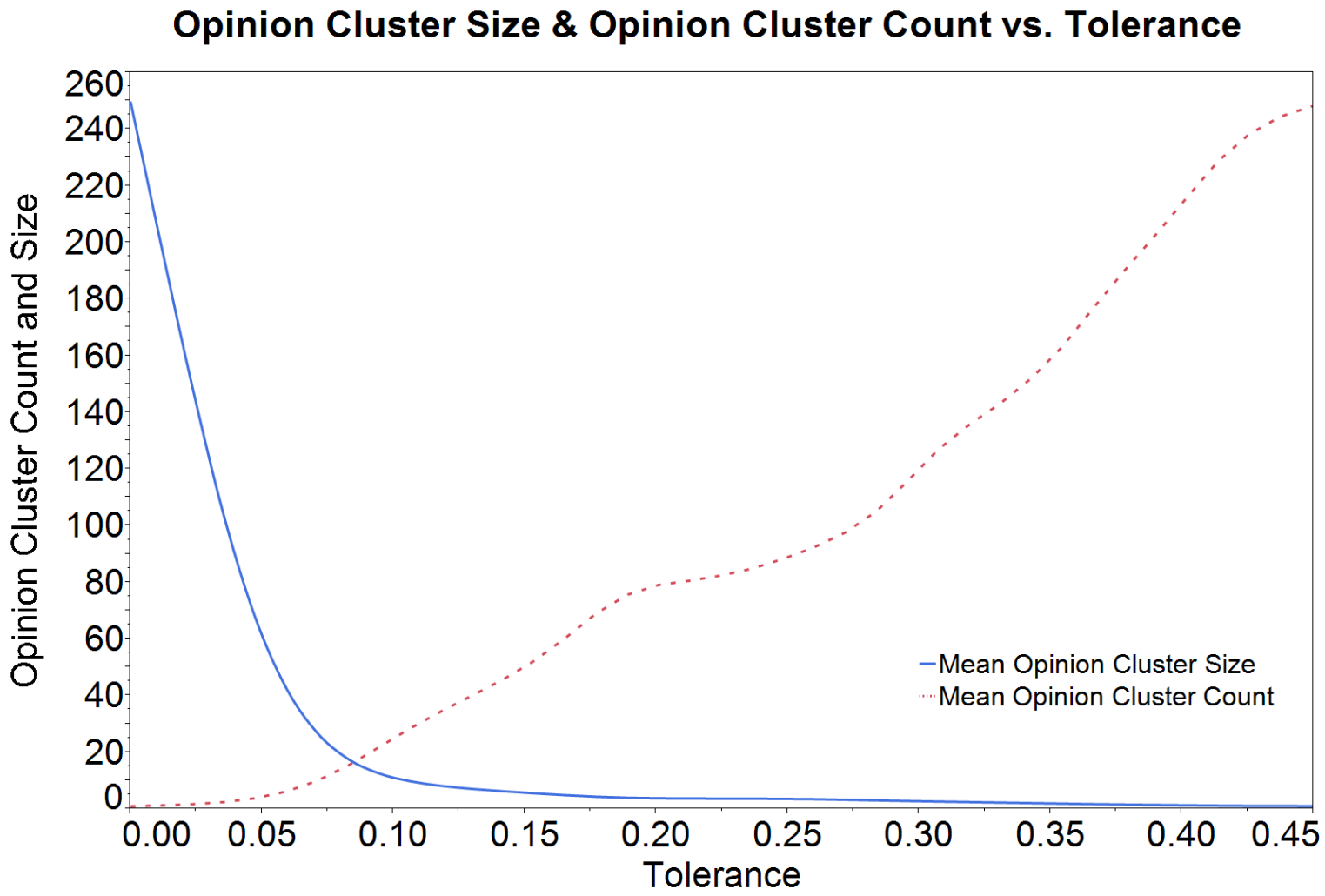
- Create a network with community structure
- 5 communities of densely connected nodes with sparse links connecting them
- Newman's modularity metric
  - Modularity value of 0.72



Tolerance Experiment Setup

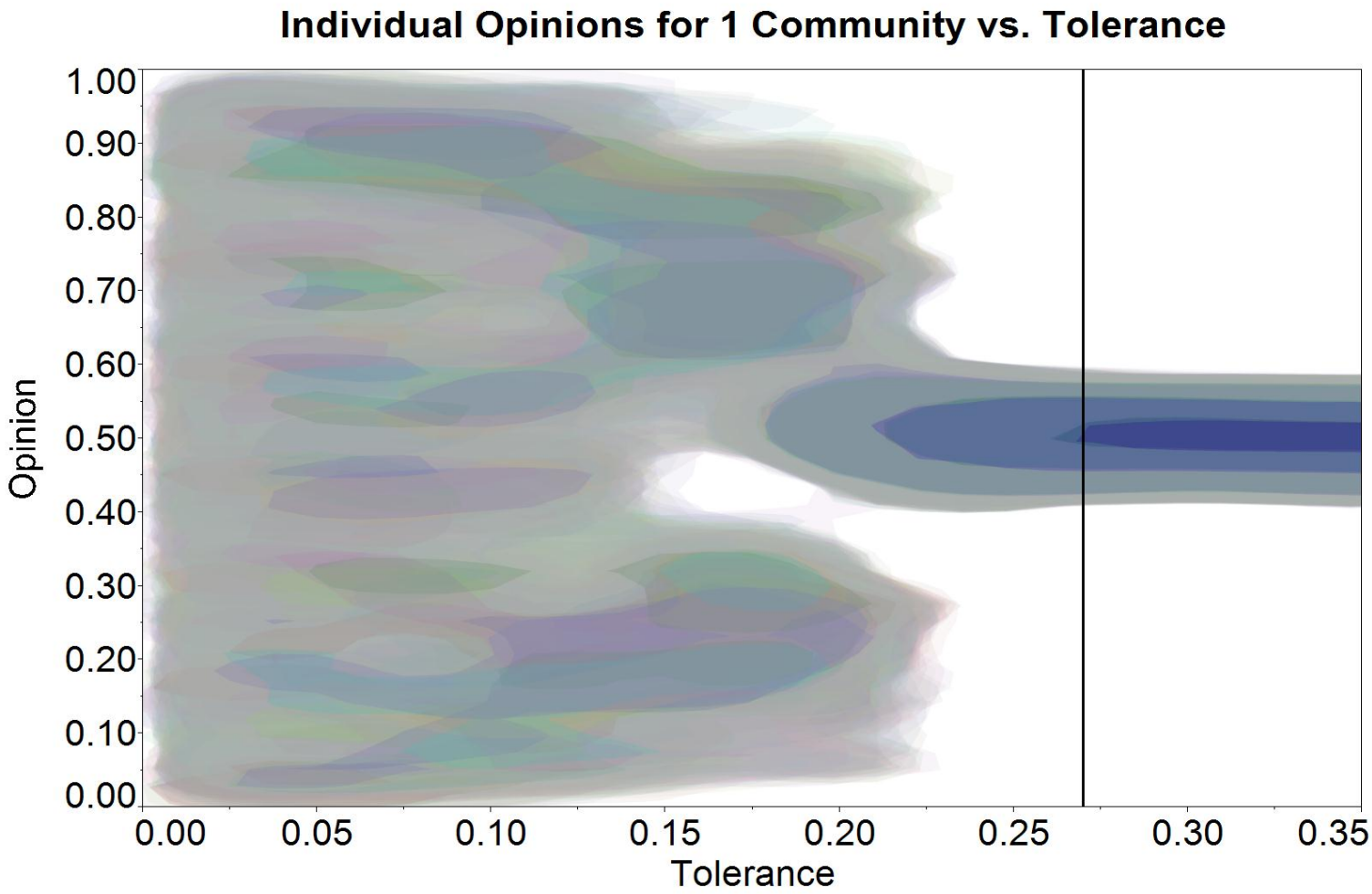
- 5 communities with 50 nodes each
  - Connect communities with 25 edges between each community
- Initial opinion drawn from uniform distribution
- Increased tolerance - 0.0 to 0.5 in series of 100 runs
- **Two questions**:
  - When do the communities form a majority opinion cluster within themselves?
  - When does the network form a majority opinion cluster consisting of the communities?

Tolerance



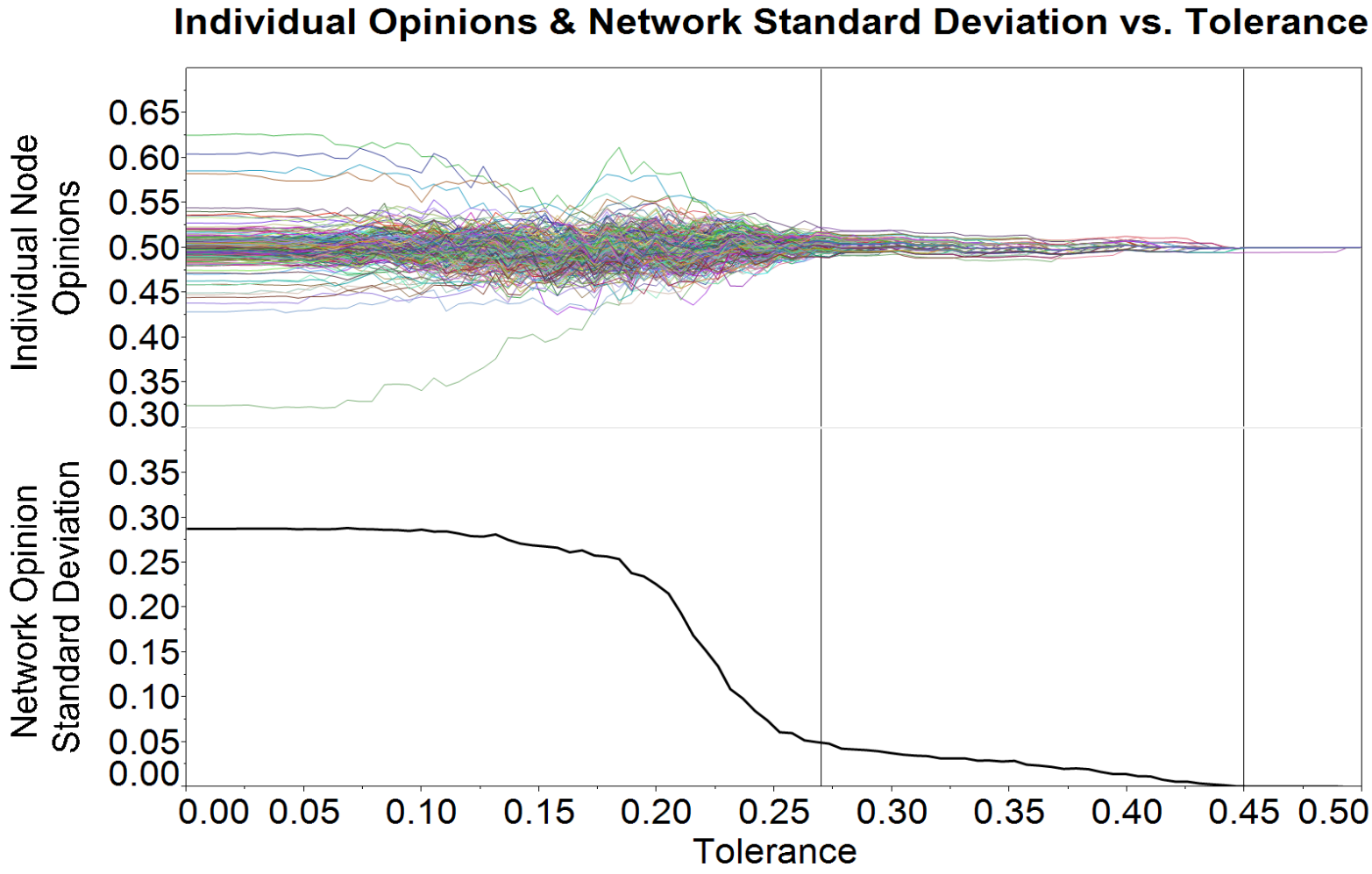
Results:
Decrease in the number of clusters and increase in the size of the clusters

Tolerance



Results:
Community forms a majority opinion cluster at ~0.27 tolerance

Tolerance



Results:
Network wide majority opinion cluster forms at ~0.45 tolerance

Topology Experiment Setup

- Heterogeneous initial opinion between communities

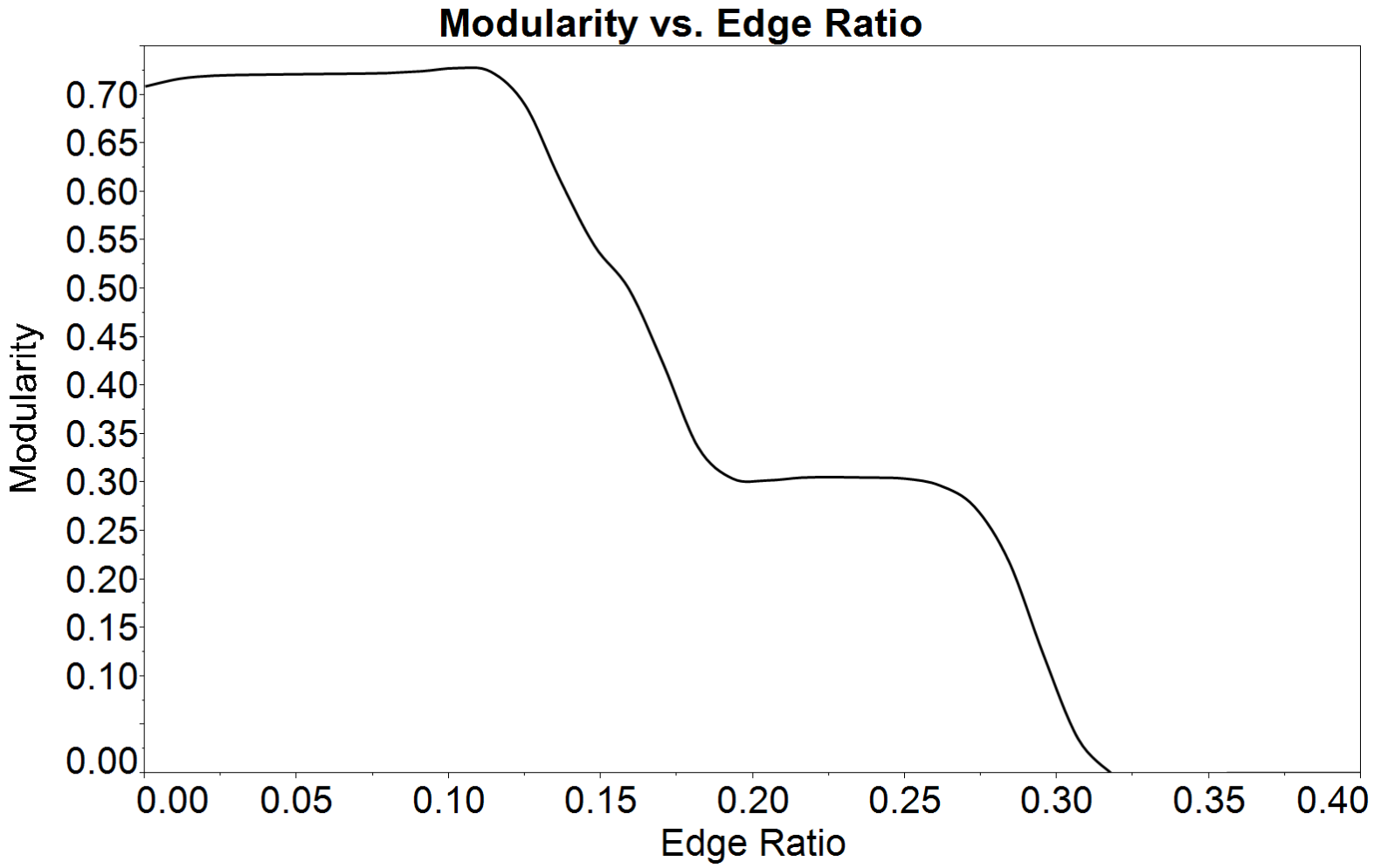
Community	Opinion Interval
Comm. 1	[0.00, 0.12]
Comm. 2	[0.22, 0.34]
Comm. 3	[0.44, 0.56]
Comm. 4	[0.66, 0.78]
Comm. 5	[0.88, 1.00]

Edge Ratio:

$$\frac{\#\ of\ between\ community\ edges}{\#\ of\ within\ community\ edges}$$

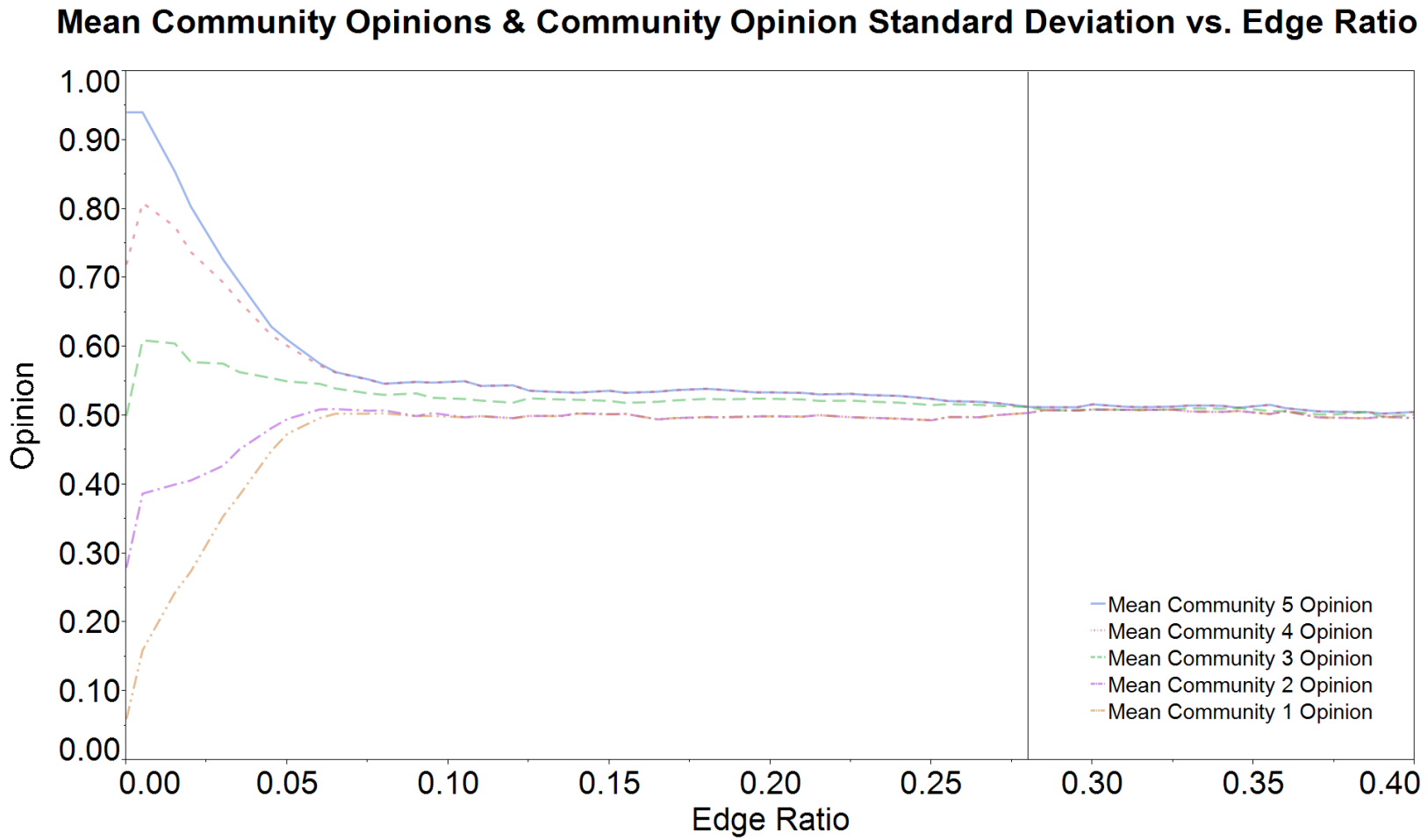
- Increase number of edges connecting communities – from 0 to 250 edges in a series of 100 runs
- Tolerance = 0.27
- **Question**: To what degree does the community structure need to be decreased for a network majority cluster to form?

Topology



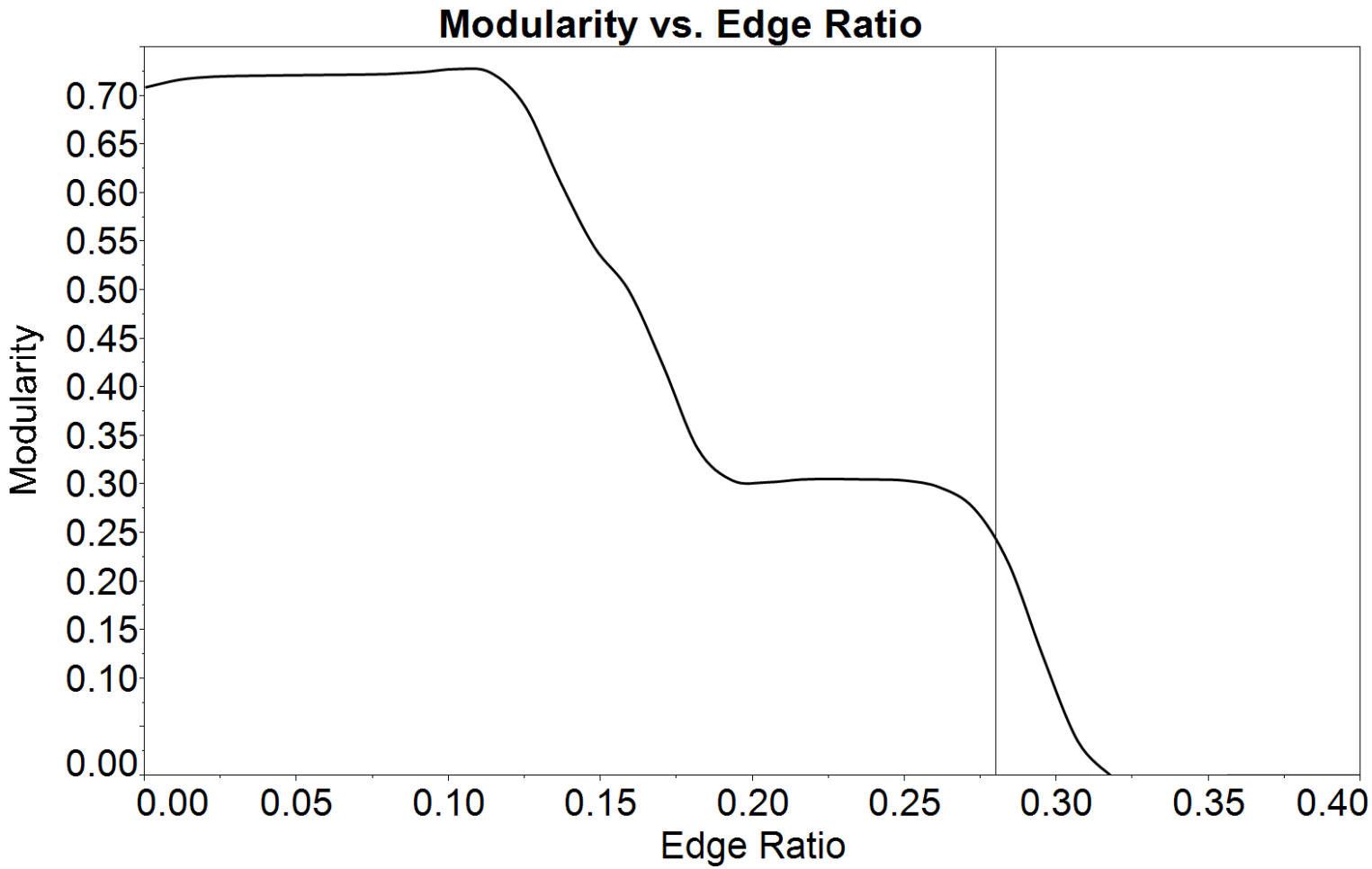
Results:
Modularity decreases with increasing edge ratio

Topology



Results:
Network majority opinion cluster forms at an edge ratio of ~0.28

Topology



Results:
Network majority opinion cluster forms during second modularity drop

Summary

- Tolerance experiment
  - Analyzed individual constraint
    - Threshold for communities to converge within themselves
    - Threshold for communities to converge together
- Topology experiment
  - Analyzed network level constraint
    - Community structure decrease to allow communities to converge together

Implications for public health policies

- Explanatory analysis
- How can public health policies be more effective acting on social networks that have community structure?
  - Understand effects of individual constraints
  - Understand effects of network constraints
- Health disparities

Questions?